BELTS AND PULLEYS FOR ELECTRIC DRIVE

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INTRODUCTION

Only a few electrically driven machines, such as centrifugal pumps and emery wheels, operate in the rated speed ranges of general purpose electric motors, permitting a direct connection of the motor and machine. Most driven machines operate at speeds different from an electric motor, thereby requiring a flexible mechanical connection that provides for speed reduction or speed-up drives. Belt drives are the most convenient means of providing for proper speed ratios. V-belt drive is replacing flat belt drive in almost all the small power drive applications because of its greater efficiency. Although V-drive gives the most satisfactory service for most power drive applications on the farm, a flat belt drive can sometimes be used to greater advantage. The information included in charts herein is based on rated motor speeds of 1700-1800 and 3450-3600 rpm. Electric motors in these rated speed classes are most apt to be found on the farm and in a given size are generally the lowest priced.

I HOW DO V-DRIVE AND FLAT DRIVE EQUIPMENT DIFFER?

Nearly everyone is familiar with pulleys and belts. However, some of the special characteristics are not so well known and are worthy of discussion.

V-Belts

V-belts are made in five standard cross-sectional sizes to serve all but the very small power drives and some special drives. For convenience and simplicity, these V-belt cross sections are designated throughout the V-belt industry by the letters A, B, C, D, and E. In general, these belts are for drives transmitting one-half horsepower or more at standard electric motor speeds. However, the A-Section belt can be used with one-third or one-quarter horsepower motors if pulley diameters are not less than three inches. A and B Section V-belts are the sizes best suited to the usual belt drive applications found on the farm. The following chart shows the five standard V-belt cross section dimensions.

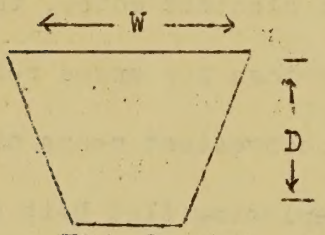


Fig. 1

Cross Section	A	B	C	D	E
W	1/2"	21/32"	7/8"	1¼"	1½"
D	11/32"	7/16"	9/16"	3/4"	1"

The leading V-drive manufacturers each also make a set of V-belts for fractional horsepower drives. The cross sectional dimensions of these belts have not been completely standardized and vary slightly, depending on the manufacturer. Fractional horsepower V-belts are made principally for small diameter single groove V-pulleys used with household appliances, small machinery, and shop equipment where pulley space and clearance is limited. These belts are made to fit pulley grooves 3/8, 1/2 and 5/8 inches wide, and hence are often described by these widths. The one-half and five-eighth inch sizes are the same approximate width as the standard A and B section belts, but are not quite as thick. The thickness is reduced about 1/16" and 3/32" respectively. The 3/8" size is approximately

7/32" thick. The thinner, more flexible fractional horsepower belts flex and bend more readily over small diameter pulleys than do the standard A or B-Section belts.

Standard V-belts are made in a continuous loop. Belts of the more common sizes can be obtained in the following lengths or outside circumferences. These limits are approximate.

Fractional Horsepower Belts	-	20 - 100 inches
A-Section Belts	-	26 - 128 inches
B-Section Belts	-	35 - 300 inches

V-Pulleys

A series of V-Pulleys is made to match each of the Standard V-Belt cross sections. Each series of pulleys for a particular V-Belt cross section has definite groove dimensions and spacing which are different from those on pulleys matching other belt cross-sections. Since A and B Cross-section belts serve a great majority of general V-Drive requirements, V-Pulleys for these two belts are made as standard or stock items in a wide range of diameters and face widths having from one to six grooves. The B-Section V-Pulley having six grooves or less is commonly designed as a combination pulley which will accommodate either A or B-Section belts. Since the groove spacing is for standard B-Section belts, these pulleys should not be used on the same drive with a pulley grooved for A-Section belts only. The one-half inch and five-eighth inch fractional horsepower V-Belts will fit the combination A and B-Section V-Pulleys. However, a set of light duty single groove fractional horsepower pulleys is made to especially match these belts and this combination is most efficient. The three-eighth inch V-Belt is matched by a light duty pulley with a three-eighth inch groove.

Diameters of V-Pulleys are usually specified by pitch diameter (or effective diameter), which is slightly less than outside diameter. With a combination A and B belt V-Pulley, the pitch diameter is less when an A-Section belt is used than when a B-Section belt is used because the A-Belt rides deeper in the groove. This actual difference in pitch diameter is about 0.4 inch and is illustrated in the following sketch.

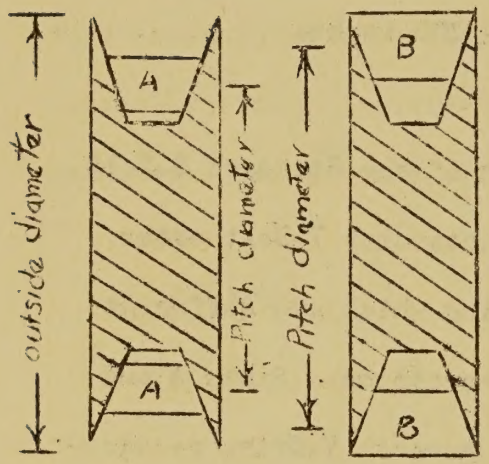


FIG. 2

V-Pulleys are either bored to fit the motor shaft directly, or can be obtained with a bushing of the correct bore, over which the pulley fits. One pulley can be used on several shafts of different motors simply by having several bushings with the proper bores. If it is necessary to order a V-pulley by mail, be sure to specify the bore, and if a bushed pulley is desired, this should be indicated also or else an unbushed pulley is likely to be sent.

With general purpose electric motors used to drive several pieces of power equipment, a combination of speeds is often desirable. Adjustable pitch and three or four step driver pulleys are made for this purpose. The face of a step pulley is evenly divided into steps, each of a different diameter, and the speed is changed by shifting the belt from step to step. The sides of adjustable pitch pulleys can be moved together or apart to change the groove widths. This allows the belt to ride higher or lower and changes the speed accordingly. Some manufacturers make adjustable pitch pulleys with up to ten grooves to match each of the V-Belt cross sections.

Flat Belts

Flat belts are made of several materials, including canvas, rubber, leather, and rubberized fabrics. The thickness of rubber and fabric belts is commonly denoted by the number of plies. These belts are most commonly available in two to six-ply with widths from one to six inches. The heavy belts are made in whole inch widths, while some of the light belts are available with in-between widths such as $1\frac{1}{2}$ inches or $2\frac{1}{2}$ inches. Leather belts are usually denoted by the duty they will perform, such as light duty, medium duty, heavy duty, double duty, etc. The belt thickness varies accordingly. A light duty leather belt is generally comparable to a two or three-ply rubber belt. As a general rule, five and six-ply belts have very little practical use with general purpose farm electric motors in the 1750 or 3500 rpm rated speed classes. The pulleys used with these motors in order to stay within belt velocity limitation are usually too small for these belts to bend and flex around efficiently. The heavy belts are for slow speed, large power drive needs.

Flat Pulleys

Flat pulleys are made of wood, steel, or cast iron, and one commonly available pulley has a fiber composition face. This type of pulley is properly referred to as Rockwood. Standard or stock Rockwood pulleys usually vary by one-half inch in face widths and diameters from one size to the next, whereas the other standard pulleys vary one inch from one size to the next.

II WHAT CONSIDERATIONS APPLY TO ALL BELT DRIVES?

Belts and pulleys should be a matched combination that will efficiently drive the driven equipment at proper speed. Several factors must be determined before the most efficient drive can be selected.

Speed Ratios

This is the speed ratio between the driver and driven pulleys. The following formula is used to determine the diameter of the driven or driver pulley when the diameter of one or the other is known or has been selected:

$$\frac{\text{Motor Speed (rpm)}}{\text{Desired Driven Speed (rpm)}} = \frac{\text{Driven Machine Pulley Diameter}}{\text{Motor Pulley Diameter}}$$

V-Drives will operate satisfactorily with greater speed ratios than flat drives. The general limiting speed ratio for V-drive is 8 to 1; for flat drive 6 to 1. When speed ratios exceed these limits, it is usually better to use a jack shaft.

Jack Shaft

This is a shaft mounted in a standard which is placed between the driven machine and the motor. The shaft has two pulleys. By varying the diameter of these in relation to one another, a speed reduction or speed-up can be effected.

Belt Velocities

The maximum recommended belt velocity is 5000 feet per minute for both flat and V-belts. Velocities in excess of this figure tend to cause slippage because as centrifugal force increases it will throw the belt away from the pulley. Belt velocity in feet per minute is easily computed by multiplying the circumference of the driver pulley in feet times the rpm of the pulley. Table I shows belt velocities for various pulley diameters at 1750 and 3450 rpm.

TABLE I
Belt Velocities

Pulley Diameters	Motor Speeds	
	1720	3450
3"	1350	2829
4"	1800	3772
5"	2250	4716
6"	2700	
7"	3150	
8"	3605	
9"	4055	
10"	4505	
11"	4955	

Belt Horsepower Ratings

Each V-Belt cross section is made to withstand in continuous use a certain maximum pull in accordance with its cross-sectional area. Each flat belt is made to withstand a maximum pull per inch of width. A pull or force does more work in a definite period of time, and this produces more power when traveling at high velocities than when traveling at low velocities. Therefore, belt horsepower ratings are based primarily on belt velocities. Good belt drive practice calls for the selection of the largest diameter drive pulleys and the lightest belts consistent with power drive requirements and belt limitations on belt velocities, space and speed ratios.

The length or circumference of a belt for a particular drive can be estimated as twice the center distance plus one-half the outside circumference of each pulley. When greater accuracy is desired, use the following formula:

$$\text{Length} = 2C + 1.57\ (D + d) - \frac{(D+d)^2}{4C}$$

Where C = Center distance
D = Diameter of large pulley
d = Diameter of small pulley

Note: If pulley pitch diameters are used, pitch belt length circumference will be the result instead of outside belt circumference.

The ideal center distance between pulley centers for V-drives is one to one and one-half times the diameter of the largest pulley. Center distance for flat drives can vary considerably, but should be generally greater than for V-drive. However, excessive center dis-

TABLE II
Flat Drive Center Distances

Speed Ratio	1-4 hp.	5-9 HP
2 to 1	4 ft.	6 ft
3 to 1	5 ft.	8 ft.
4 to 1	7.5 ft.	10.5 ft.
5 to 1	10 ft.	12 ft.

tances are objectionable because the weight of the belt increases the tension and the belts tend to whip or sway. Short center distance requires high initial belt tension which is difficult to maintain and leads to overheating and bearing wear. Table II indicates minimum center distances in relation to the horsepower of the drive and speed ratios.

Fixed Center Drives

Where location or arrangement of equipment is such that center distances between pulleys cannot be altered to provide proper take-up adjustment, a mechanical tightener, such as an idler, is required. This applies especially to vertical drives which are more troublesome with flat belts than with V-Belts. To insure satisfactory performance and maximum belt life, the following considerations are pertinent.

1 - The idler pulley should be approximately the same size as the smallest pulley in the drive. A V-drive idler should have the same groove spacing and dimensions as the other pulleys in the drive.

2 - The idler should be aligned at all times and the supporting framework rigid and non-vibrating.

3 - Idlers should be located on the inside of V-belts, preferably on the slack side of the drive, as close to the large pulley as possible. Idlers should be located on the outside of flat belts near the small pulley. If necessary a flat pulley idler placed on the outside of V-belts can be used.

Special Drives

Although it is never desirable, it is sometimes necessary to cross flat belts to have the proper direction of rotation. V-belts should not be crossed. With crossed flat belts, the center distances should be as great as possible, and the crossings as near the midpoint between pulleys as possible. The speed ratio should not exceed 4 to 1 and belts 8 inches or wider should not be crossed.

An occasion may arise where it is desired to belt from a horizontal shaft to a vertical shaft. This is a quarter-turn drive illustrated by Fig. 3. Flat belt quarter-turn drives are very troublesome and the use of V-belts is much preferred. The use of V-belts with this type drive is subject to several limitations.

1 - The pulley speed ratios should not exceed $2\frac{1}{2}$ to 1.

2 - The center distance should not be less than six times the diameter of the large pulley plus the face width of the pulley. Where the angle through which the belts are required to turn is less than 90° the center distance can be somewhat less. For 45° turns, this distance should not be less than four times the diameter of the large pulley plus the face width.

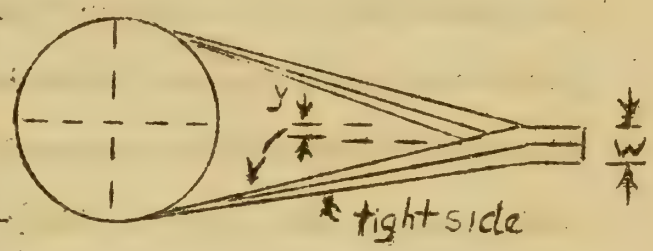


Fig. 3

3 - The center line of the horizontal shaft should be at least $1\frac{1}{2}$" higher than the center of the pulley on the vertical shaft (distance Y) for each 60 inches of center distance.

4 - Horsepower ratings of V-belts on this type of drive are 75 percent of those on regular drives. Refer to note with TABLE II when selecting V-belts for quarter-turn drives.

5 - Special deep groove pulleys must be used and the tight side of the drive should be on the bottom.

III HOW CAN I SELECT THE PROPER BELT DRIVE?

V-Drive

Table III is a practical guide for selecting the number and size of V-belts to use in accordance with the horsepower of the motor and the diameter of the driver pulleys. It allows at least an extra 20 percent in belt capacity to take care of normal overload and operations under adverse conditions such as in dust, high temperature, or wet locations. Belt velocities somewhat in excess of 5000 feet per minute will result if a drive pulley greater than 5.4 inches in diameter is used with a 3450 rpm motor, or greater than 11 inches with a 1750 rpm motor. In the

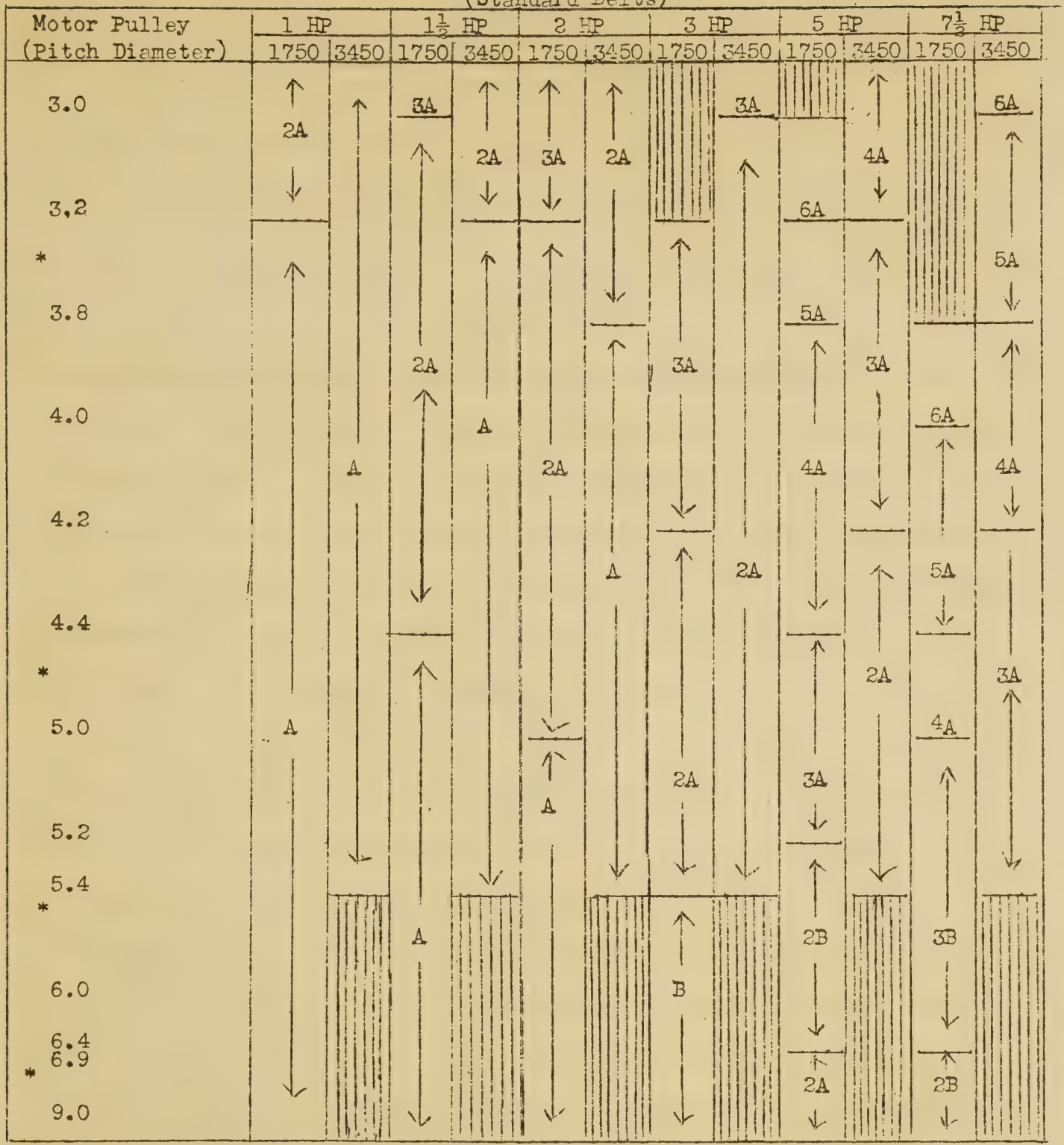
common sizes, pitch diameters for A and B-Section V-Pulleys increase by .2 inch from one standard pulley to the next larger size. Some of the intermediate diameters are not shown in Table II as indicated by the symbol * The belt selection for these intermediate diameters is the same as for the next larger pulley shown in the chart. For instance, the proper selection for a 3.6" pulley on a 1 horsepower 1750 rpm motor is one A-belt the same as for 3.8" pulley. The minimum recommended pulley pitch diameters for A and B-Section belts are 3 and 4.6" respectively. Whenever B-Section belts are specified in the table, A-Belts can be used safely if an extra belt is used.

TABLE III

Belt Selection

(Size and Number)

(Standard Belts)



*Some intermediate diameters omitted. Belt Selections for them same as the next larger diameter shown.

Note: For quarter turn drives, use an extra belt unless the number of belts specified above covers several pulley diameters. In these instances the Table value is sufficient for the larger or largest pulley diameters covered.

As long as pulley diameters are not less than three inches, one A-belt is suitable for motors 3/4 horsepower or less. For the small fractional horsepower motors, fractional horsepower belts, however, will give the best results. Under normal conditions a one-half inch fractional horsepower belt is suitable for one-eighth up to and including one-half horsepower motors. A five-eighths inch fractional horsepower belt is suitable for three-quarter horsepower motors.

Flat Drives

Table IV gives horsepower ratings per inch width for one manufacturer's rubber flat belts in accordance with driver pulley diameters. It is a guide to proper flat belt widths and can be applied to leather or fabric belts by using discretion in comparing these belts with rubber belts. The horsepower of the belt drives divided by the value in the table for the desired pulley-belt combination gives the proper belt width to transmit the power. Use a belt drive horsepower somewhat in excess of the motor's rated horsepower in order to allow a margin of safety for overloads or other unusual conditions. The heavier belts are, of course, stiffer and require larger diameter pulleys for efficient operation. The table indicates that 5 or 6 ply belts have little application with electric motors having rated speeds in the ranges 1700-1800 or 3450-3600 rpm. As an approximate guide, the minimum pulley diameters recommended for 3, 4, 5, and 6 ply rubber belts are 3, 4, 5 and 8 inches, respectively. As belt velocities approach 5,000 feet per minute, the lightest belt suitable for the load should be used to avoid excessive slippage. The most desirable speeds for flat drives are 3000 - 3500 feet per minute.

TABLE IV

Driven Pulley Diameter	HORSEPOWER PER INCH AT 1750 & 3500 RPM							
	3-Ply		4-Ply		5-Ply		6-Ply	
	1750	3500	1750	3500	1750	3500	1750	3500
3	.83	1.3	.88	1.5	-	-	-	-
4	1.3	2.1	1.5	2.1	-	-	-	-
5	1.9	3.0	2.1	3.0	-	-	-	-
6	2.6	-	2.8	-	2.5	-	-	-
8	4.0	-	4.4	-	4.3	-	3.8	-
10	5.0	-	5.8	-	5.9	-	5.8	-

V-Flat Drive

Many power driven farm machines are normally equipped with flat pulleys, expecially those machines more or less intended for tractor power. In the changeover to electric power and economical V-belt drive, it is often possible to keep the flat pulley on the driven machine and use a V-pulley on the motor only. The combination is called V-flat drive, and to work efficiently the following conditions should be observed:

1 - As a rule of thumb, a speed ratio of 3 to 1 or more will give the most favorable operation.

2 - The center distance should be about equal or slightly less than the diameter of the flat pulley.

3 - Flat pulley should be 12 inches or more in diameter.

Longer distances are permissible, but this reduces the arc of belt contact with flat pulley. As contact on the flat pulley is reduced, more belts are needed to prevent slippage. V-flat drives are not recommended with flat pulleys less than 12 inches in diameter. Of course the face of the flat pulley must be wide enough to accommodate the number of belts required for the drive. The pitch diameter of a flat pulley is equal to its outside diameter plus the thickness of the V-Belt section to be used. This is important in figuring speed ratios and belt lengths.

IV WHAT OPERATING CONDITIONS ARE IMPORTANT?

Belt Replacement

To mount or replace a belt, the take-up adjustment should be loosened until the belt can be slipped over the pulley by hand. A V-belt should NEVER be rolled or pried on or off with a bar or other instrument. After the belt is in place, tighten the take-up adjustment until the tension is reasonable. The tension should be just great enough to prevent slippage. When in operation, the tight side should be in a straight line from pulley to pulley and the slack side should have a slight bow. After the first eight hours of operation, A-Belt tension should be checked, as the belts will set themselves slightly in the pulley grooves and tend to slacken. Periodic checks thereafter will insure efficient operation. On V-drives using two or more belts, the entire set should be changed whenever one belt becomes damaged or broken. For multi-belt drives, some manufacturers supply pre-stretched matched length belts which will each take a proportionate share of the load. If new belts are used with old ones, the new belts will take all the load until they have stretched to the length of the old belts. This greatly shortens the useful life of the replaced belts.

Belt Tension

Under normal operating conditions, V-Belts will perform satisfactorily with less tension than flat belts. V-Belts tend to squeeze into the grooves of the pulley and have a better grip than flat belts. Belts should never be run tighter than is necessary to prevent slippage. With flat belt drives, belt dressings are often needed to maintain friction between the belt and the pulley. This dressing is not used with V-Belts. Excessive tension merely increases belt wear and wear on the shaft bearings. Improper center distances, excessive speed ratios, and excessive belt speeds can all cause slippage.

Rockwood Drive

A general purpose integral horsepower motor is more useful if it is mounted on a dolly or cart so that it can be moved about. Fractional horsepower motors can also be made easily portable (See lesson on home-made equipment). These portable motors are quickly belted to and unbelted from driven equipment by utilizing the pivot principle. The weight of the motor maintains belt tension. When the motor is tipped toward the machine, the belt is loosened and can be easily removed or the motor dismounted. Proper belt tension is provided by adjusting the location of the pivot. This type of drive is popularly known as Rockwood Drive. Motor rails for pivoting the motor can be made of 3/4 inch pipe, a broom handle, or they can be purchased from hardware or mail order stores ready for attachment.

SPEED CHART INSTRUCTIONS

Table VI is a handy means of obtaining pulley combinations to obtain approximate speeds. It is not intended for use where exact speeds are essential. The user can quickly determine the speeds he will obtain, with definite p lley ratios and certain size pulleys that may be available, with Table VI. These ratios and speeds are obtained only when the motor has a rated speed of 1750 rpm.

It will be noted that the division in pulleys between $2\frac{1}{2}$ inches in diameter and 3 inches in diameter indicates those to be used on fractional horsepower motors and on motors one horsepower or larger in size. This division has been made for practical purposes and general operating conditions, but it whould be understood that, where necessary, pulleys smaller than three inches can be used on larger motors and pulleys larger than two and one-half inches can be used on the smaller motors.

The stair-steps indicate the location of approximately equal speeds with the various pulley combinations. Driven speeds as indicated in the left hand column are closely approximated by following the stair-steps. In using this chart to select pulleys, the nearest approximate speed to that desired can be located by following the staggered stair-steps within the general speed range. For illustration, if a driven speed of 345 rpm were desired, the user would follow the stair-steps connected to the general 300 rpm speed on the left hand side. Following the stair-steps down, it will be found that the nearest approximate speed is either 350 or 340. Since there is a small amount of slippage, even with "V"-Belt drives, it would be better to select a pulley combination that would give a calculated speed of 350 rpm, depending on the slippage, to bring the speed to approximately 345. Pulley combinations that will give this desired speed are a two-inch pulley on the motor and a ten-inch pulley on the driven machine. These pulley sizes are found by following the vertical lines to the top and the horizontal lines to the right. The two-inch pulley for the motor would indicate that a fractional horsepower motor would be used. If the pulleys are to be used with a large motor, then it will be necessary to follow the staggered line down to a point where a speed of 350 rpm is found under the pulleys for the larger motors. In this case, the chart indicates that a four-inch pulley on the motor and a twenty-inch pulley on the driven machine would be required for a 350 rpm speed.

Since a twenty-inch V-Pulley would be very expensive to purchase, the user may wish to select a flat pulley of twenty inches diameter and use a V-flat drive. In fact, practical operating conditions generally indicate that the driven machine should be fitted with flat pulleys rather than V-pulleys when pulley diameters greater than fourteen inches are required.

It should also be noted that speeds greater than 5000 rpm are generally considered dangerous and should not be used except where such speeds are required and on machines that are especially designed for those speeds. It is very dangerous to use emery wheels and grindstones at excessive speeds because of the danger of the wheel exploding due to the large centrifugal force obtained at high speed.

CONCLUSIONS

1 - A and B-Section V-belts will serve nearly any farm power drive using a general purpose electric motor.

2 - Within limitations, belt drives should be designed with light belts and high belt velocities.

3 - Belt drives should be laid out as near to the horizontal plane as possible

4 - Light flexible belts must be used with small pulleys.

5 - Belt tension should be just enough to prevent slippage.

6 - V-Belts, rather than flat belts, should be used wherever possible with electric motors.

7 - V-flat drives are cheaper to install and are recommended on light loads.

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